CVC and $\tau^- \to \eta(\eta')\pi^-\pi^0\nu_\tau$

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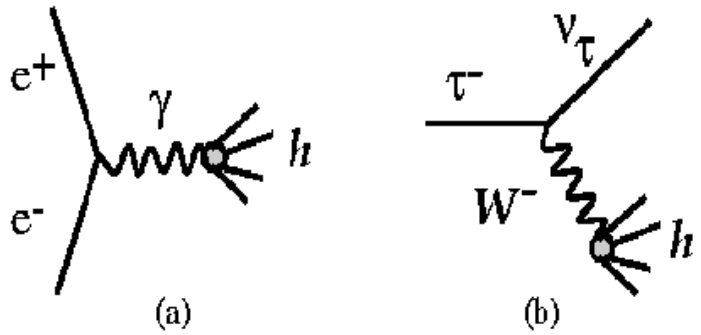
Outline

1. CVC basics
2. $\tau^- \to \eta\pi^-\pi^0\nu_\tau$
3. $\tau^- \to \eta'\pi^-\pi^0\nu_\tau$
4. Conclusions

CVC Basics – I



The allowed $I^G J^P = 1^+1^-$:

$X^- = \pi^-\pi^0, (4\pi)^-, \omega\pi^-,$

$\eta\pi^-\pi^0, K^-K^0, (6\pi)^-, \ldots$

$\mathcal{B}(V^-\nu_\tau) \sim 32\%$

For the vector part of the weak hadronic current the mass distribution of the produced hadrons is

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2 |V_{ud}|^2 S_{EW}}{32\pi^2 m_\tau^3}(m_\tau^2 - q^2)^2(m_\tau^2 + 2q^2)v_1(q^2),$$

where the spectral function is

$$v_1(q^2) = \frac{q^2 \sigma^{I=1}_{e^+e^-}(q^2)}{4\pi^2\alpha^2}.$$

Integration gives the branching fraction:

$$\frac{B(\tau^- \to X^-\nu_\tau)}{B(\tau^- \to e^-\nu_e\nu_\tau)} = \frac{3|V_{ud}|^2 S_{EW}}{2\pi\alpha^2} \int_{4m_\pi^2}^{m_\tau^2} dq^2 \frac{q^2}{m_\tau^2}\left(1 - \frac{q^2}{m_\tau^2}\right)^2\left(1 + 2\frac{q^2}{m_\tau^2}\right)\sigma^{I=1}_{e^+e^-}(q^2).$$

CVC Basics – II

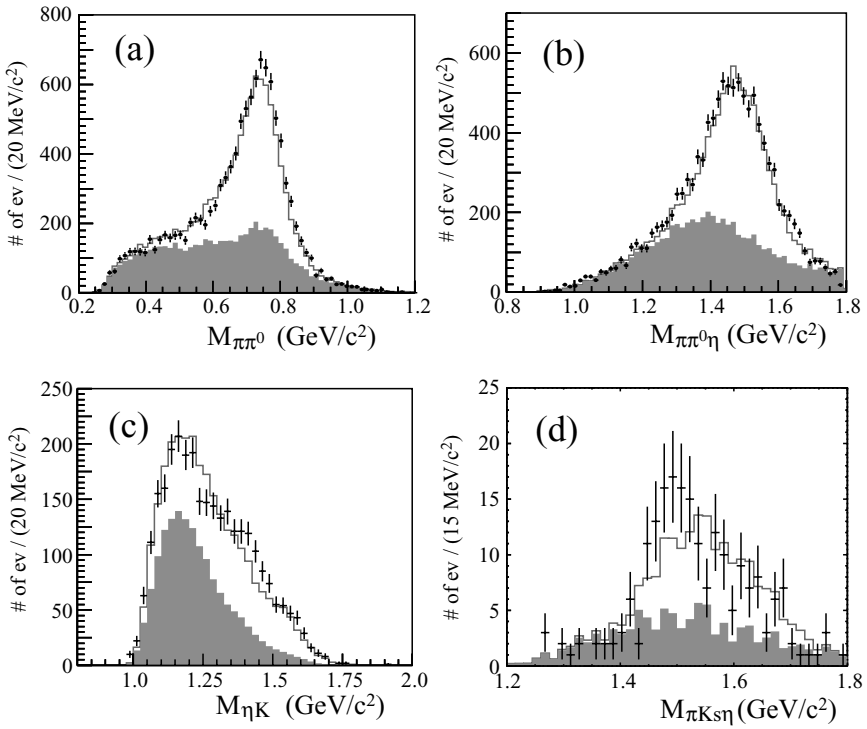
- The CVC relations are known since the pre-τ era:
  Y.S. Tsai, 1971; H.B. Thacker and J.J. Sakurai, 1971
- First CVC tests showed good agreement of the τ branchings predicted from e^+e^- with τ data (N.Kawamoto, A.Sanda, 1978; F.Gilman, D.Miller, 1978; SE, V.Ivanchenko, 1991, 1997).
- Higher accuracy of both τ and e^+e^- revealed serious discrepancies, particularly in the 2π and 4π channels: M. Davier et al., 2003
- Reconsideration of isospin-breaking corrections improved the situation in the 2π channel: M. Davier et al., Eur. Phys. J. C66, 127 (2010)
- It is interesting to analyze other possible channels

Motivation

- Together with V. Cherepanov (Phys. Inst. IIIB, RWTH, Aachen) we consider the $\eta(\eta')\pi\pi$ final state. First results in V. Cherepanov and SE, JETP Lett. 89, 429 (2009).
- For $\tau^- \to \eta\pi^-\pi^0\nu_\tau$ the old CVC estimate gave $\mathcal{B}_{\rm CVC} = (0.13 \pm 0.02)\%$ compared to the PDG-08 $\mathcal{B}_\tau = (0.181 \pm 0.024)\%$
- A new high-statistics measurement appeared at Belle in 2009
- There are new e^+e^- data from BaBar (2007) and SND (2010)
- Good knowledge of the $\eta\pi^-\pi^0(\eta\pi^-)$ spectrum may help in a search for 2nd class current $\tau^- \to \eta\pi^-\nu_\tau$
- Work is in progress on updating hadronic form factors in MC generators TAUOLA and PHOKARA with Z. Wąs and H. Czyż
- Belle is repeating the analysis of BaBar to study ISR production of $e^+e^- \to \eta\pi^+\pi^-$

A New Study of $\tau^- \to \eta\pi^-\pi^0\nu_\tau$ at Belle

In 2009 Belle performed a high-statistics study of $\tau^- \to \eta\pi^-\pi^0\nu_\tau$ and obtained $\mathcal{B} = (0.135 \pm 0.003 \pm 0.007)\%$



In general, the $\eta\pi^-\pi^0(\pi^-\pi^0)$ mass spectra are consistent with the old form factors in TAUOLA

Summary of $e^+e^- \to \eta\pi^+\pi^-$ Measurements – I

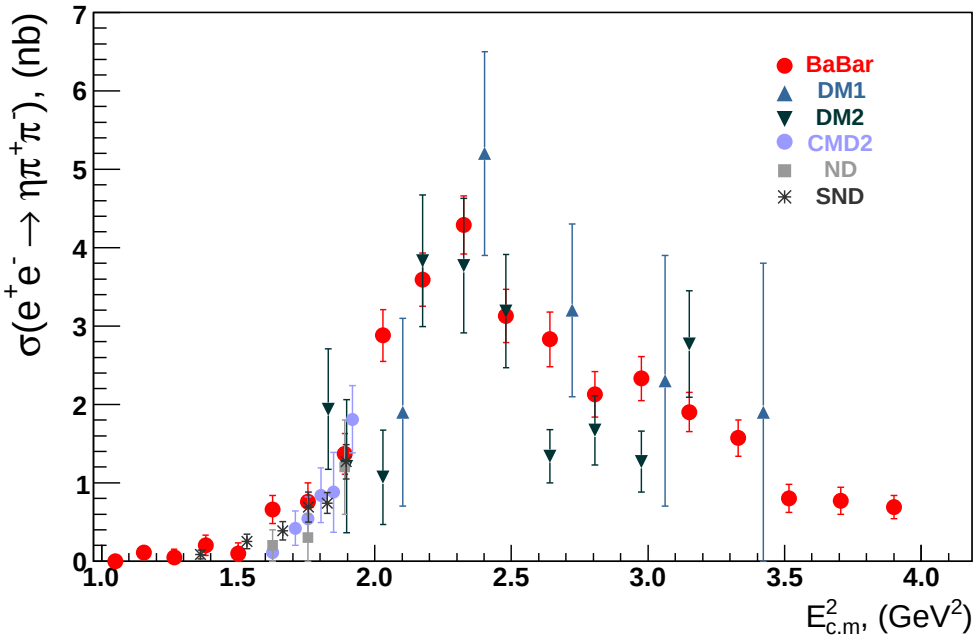
Group	$\sqrt{s}$, GeV	$N_{\rm points}$	$\Delta\sigma_{\rm stat}$, %	$\Delta\sigma_{\rm syst}$, %
ND, 1986	1.25-1.40	3	50-100	10
CMD-2, 2000	1.25-1.40	6	30-60	15
SND, 2010	1.17-1.38	6	15-60	10.5
DM1, 1982	1.40-1.80	4	30-60	10
DM2, 1988	1.35-1.80	10	25-60	10
BaBaR, 2007	1.00-1.80	16	10-60	8

BaBar studied the whole range from threshold to m_τ

B. Aubert et al., Phys. Rev. D 76, 092005 (2007)

SND: M.N. Achasov et al., JETP Lett. 92, 84 (2010)

Summary of $e^+e^- \to \eta\pi^+\pi^-$ Measurements – II



BaBar data are much more precise than those at DM1, DM2 above 1.4 GeV

Are BaBar points higher below 1.4 GeV?

Calculation of the Branching Fraction

- The parameter values are:
  $S_{\rm EW} = 1.0194$, $|V_{ud}|^2 = 0.9742$ and $\mathcal{B}(\tau^- \to e^- \nu_\tau \bar{\nu}_e) = (17.85 \pm 0.05)\%$
- No corrections except $S_{\rm EW}$ are applied
- "Old" (+ SND) and "new" (BaBar) data

Data	$\mathcal{B}, \%$
Old + SND	0.130 ± 0.015
BaBar	0.165 ± 0.015
Aver.	0.153 ± 0.018

The error of the average is inflated with a scale factor of 1.67

Comparison with Other Predictions

Author	Method	$\mathcal{B}, \%$
A. Pich, 1987	ρ'	~ 0.3
F.J. Gilman, 1987	CVC	~ 0.15
E. Braaten, 1987	ChT	$0.14^{+0.19}_{-0.10}$
G. Kramer, 1988	ChT	0.18-0.88
S. Eidelman, 1991	CVC	0.13 ± 0.02
S. Narison, 1993	CVC	0.14 ± 0.05
R. Decker, 1993	CVC+ChT	~ 0.19
B.A. Li, 1998	ChT	~ 0.19
This work	CVC	0.153 ± 0.018

Comparison with τ Experiments

Group	$\mathcal{B}, \%$
CLEO, 1992	$0.17 \pm 0.02 \pm 0.02$
ALEPH, 1997	$0.18 \pm 0.04 \pm 0.02$
Belle, 2009	$0.135 \pm 0.003 \pm 0.007$
PDG-2010	0.139 ± 0.010
$\mathcal{B}_{\rm CVC}$	0.153 ± 0.018

$\mathcal{B}$ from Belle is lower, but consistent with ALEPH and CLEO

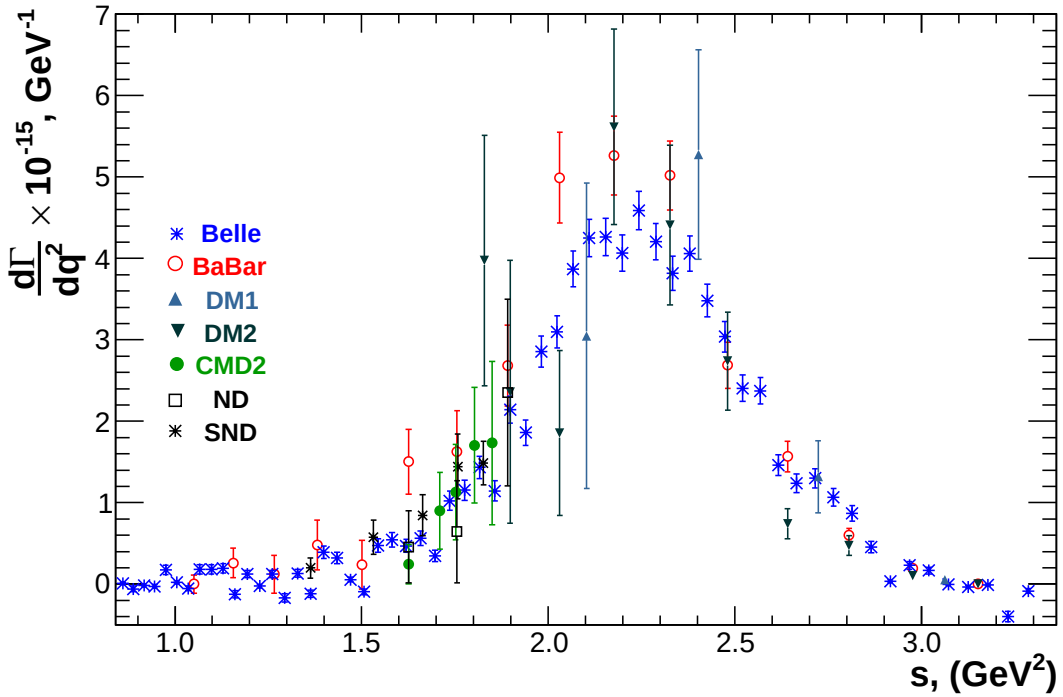
Fair agreement of $\mathcal{B}_{\rm CVC}$ with PDG-2010

CLEO M. Artuso et al., Phys. Rev. Lett. 69, 3278 (1992)

ALEPH D. Buskulic et al., Z. Phys. C74, 263 (1997)

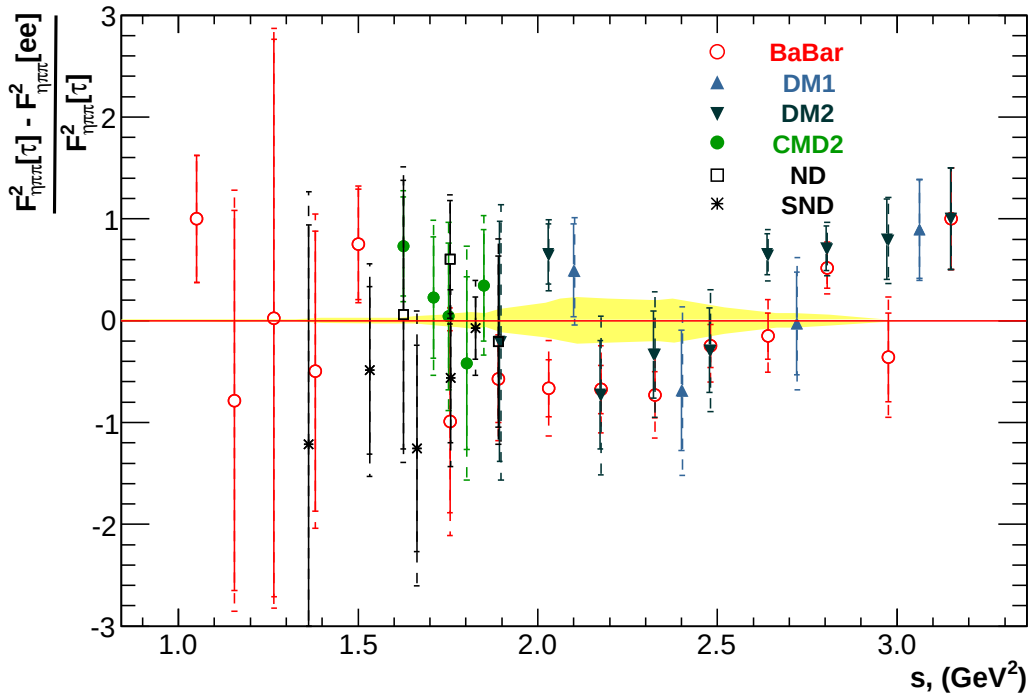
Belle K. Inami et al., Phys. Lett. B 672, 209 (2009)

Comparison with Belle – I



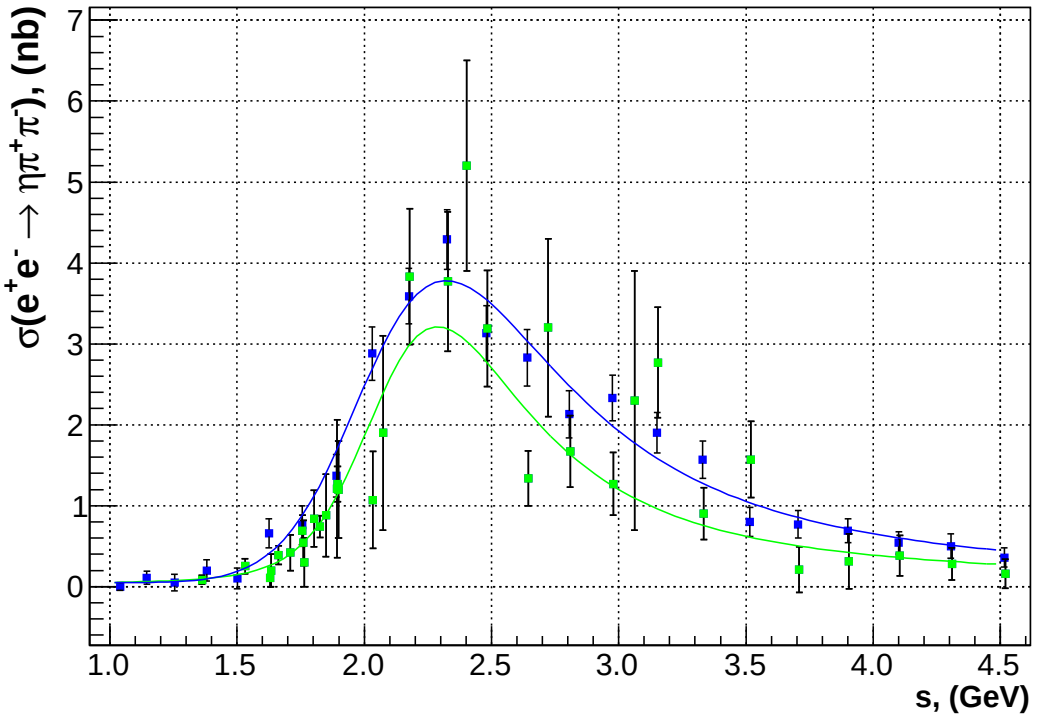
In general, τ spectra are consistent with e^+e^-

Comparison with Belle – II



This can be seen better from the "difference" plot taking into account a 5.3% syst. error of Belle

A fit of the e^+e^- data

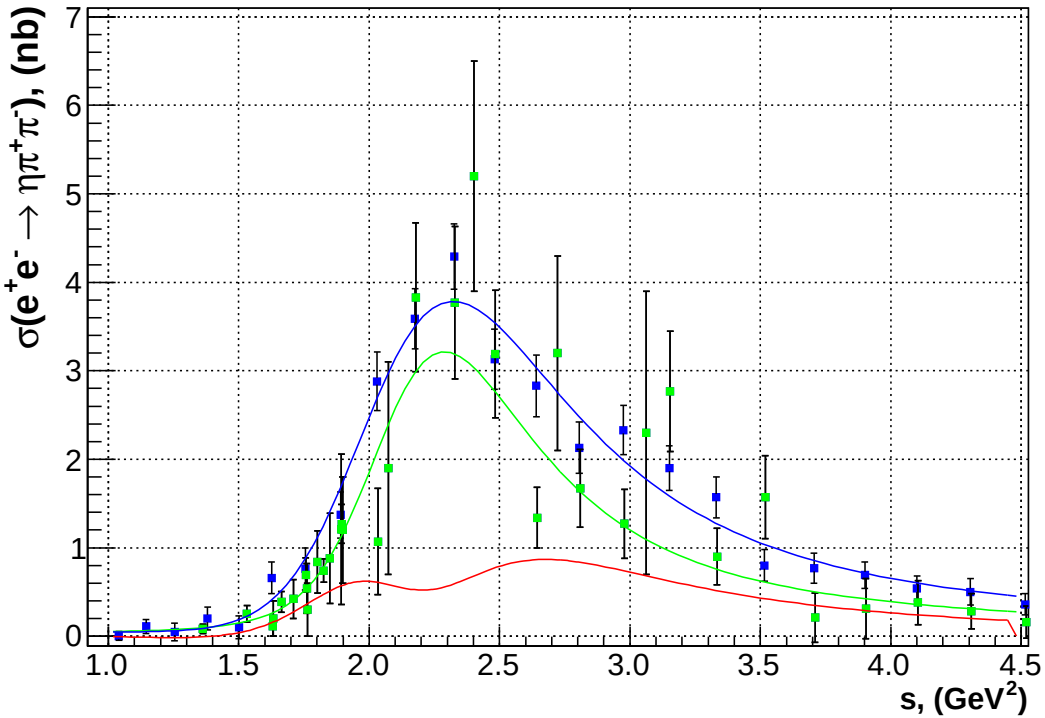


Spectra are described by the interfering $\rho(1450)$ and $\rho(1700)$

One broad resonance only is seen

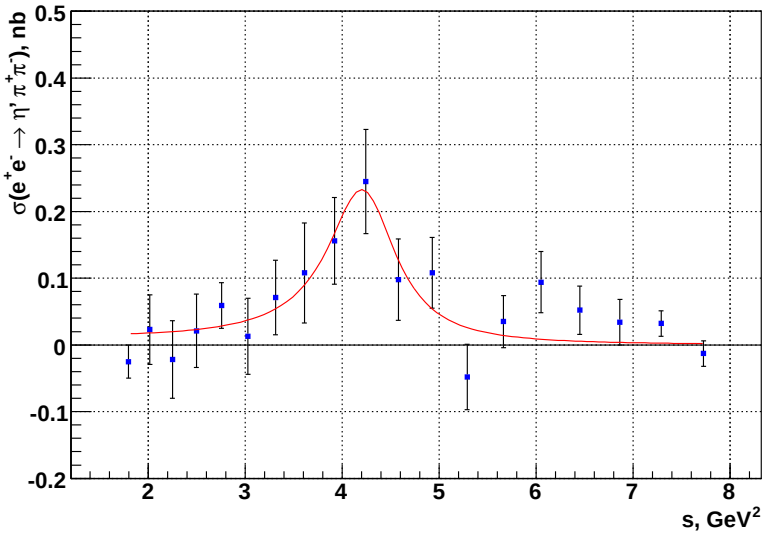
as in other isovector channels (4π)

Difference between new (BaBaR) and old + SND e^+e^- data



Some excess of the "BaBaR" data is confirmed
although critical analysis of the fits needed

$e^+e^- \to \eta'\pi^+\pi^-$



Integration of the optimal curve up to m_τ gives

$\mathcal{B} = (13.4 \pm 9.4(stat) \pm 1.3(syst) \pm 6.1(mod)) \cdot 10^{-6}$

$\mathcal{B} < 3.2 \cdot 10^{-5}$ at 90% CL

compared to the CLEO limit $\mathcal{B} < 8 \cdot 10^{-5}$ at 90% CL

An order of magnitude higher than $\sim 4.4 \cdot 10^{-6}$ from ChT

Conclusions

- The whole dataset on $e^+e^- \to \eta\pi^+\pi^-$ is used to test CVC
- Spectral functions of τ and e^+e^- are compatible
- $\mathcal{B}_{\rm CVC} = (0.153 \pm 0.018)\%$ is consistent with $\mathcal{B}_{\rm PDG} = (0.139 \pm 0.010)\%$
- Is excess of BaBar data below 1.4 GeV significant?
- From the data on $e^+e^- \to \eta'\pi^+\pi^-$ we obtain $\mathcal{B} < 3.2 \cdot 10^{-5}$ at 90% CL compared to the CLEO limit $\mathcal{B} < 8 \cdot 10^{-5}$ at 90% CL
- Update of TAUOLA and PHOKHARA in progress